AD-A097 005 AIR FORCE SYSTEMS COMMAND WASHINGTON DC F/G 12/1
SPLIT LEARNING CURVES,(U)
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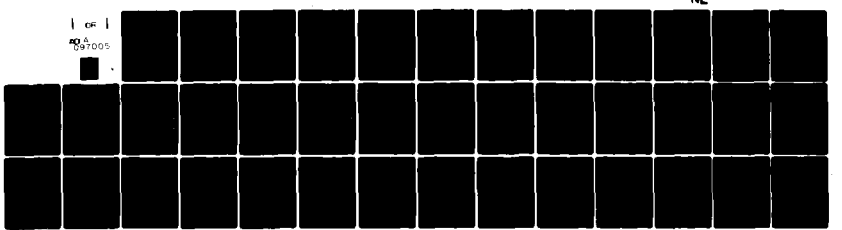

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# Split Learning Curves

Prepared by:

Allen/Fatkin

HQ AFSC/ACCE

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MAR 30 1981

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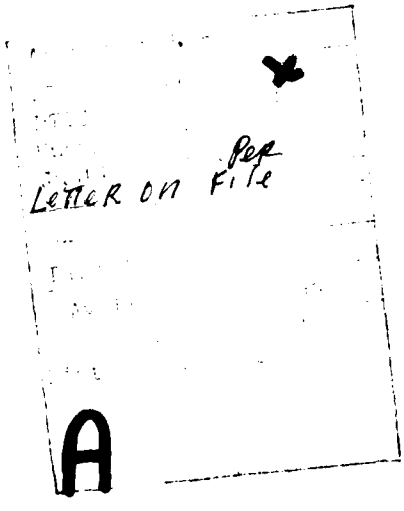
3780 M(V+1)=((S2+S3)/(A5*Q1(V+1)))**(1/B6)
3785 T7(V+1)=A5*M(V+1)**B6
3790 IF Q(N-U-1)<N9 GO TO 3910
3800 IF L(N-U-1)>N9 GO TO 3910
3810 S4=(A5*(N9**(B6+1)-L(N-U-1)**(B6+1)))/(B6+1)
3820 S5=(A6*(Q(N-U-1)**(B9+1)-N9**(B9+1)))/(B9+1)
3830 M(N-U-1)=((S4+S5)/(A5*Q1(N-U-1)))**(1/B6)
3835 T7(N-U-1)=A5*M(N-U-1)**B6
3840 IF M(N-U-1)<N9 GO TO 3860
3850 M(N-U-1)=((S4+S5)/(A6*Q1(N-U-1)))**(1/B9)
3855 T7(N-U-1)=A6*M(N-U-1)**B9
3860 GO TO 3601
3900 M(V+1)=((Q(V+1)**(B5+1)-L(V+1)**(B5+1))/(Q1(V+1)*(B5+1)))**(1/B5)
3903 T7(V+1)=A4*M(V+1)**B5
3905 N8=Q(V+1)
3907 GO TO 3790
3910 M(N-U-1)=((Q(N-U-1)**(B6+1)-L(N-U-1)**(B6+1))/(Q1(N-U-1)*(B6+1)))**(1/B6
)
3913 T7(N-U-1)=A5*M(N-U-1)**B6
3915 N9=Q(N-U-1)
3920 GO TO 3601
7000 FOR I=9 TO 14
7010 R(K,I)=9999
7020 NEXT I
7030 GO TO 1790
9000 END
```



# Split Learning Curves

The term "learning curve" describes the improvement in efficiency of producing an item in quantities larger than one. Although the phenomenon has been known by other names and many different mathematical formulations on the learning curve have been developed, the basic concept is accepted throughout government and industry.

Learning curve theory was developed from the observation that as more and more of the same item are produced, less time is spent on subsequent items. In a strict interpretation for a recurring production process, this theory would apply only to hands-on-labor. The theory has been developed and extended through the years to include cost improvements for recurring material costs. In some cases rough analyses are made using only the total cost of an item when the detailed breakouts are not available.

The current methods of calculating recurring production costs assume that actual performance can adequately be described by a single learning curve slope and that this slope can be used as a basis for extrapolation of future performance. This assumption may be valid when using learning curve theory to project labor hours. However, if we extend the theory to include other reccurring costs in addition to labor, i.e., material, inconsistencies can occur. Some of these are:

1) Initial lots may contain some nonrecurring costs because separation

of recurring and nonrecurring costs is sometimes difficult.

2) Production efficiency during build-up to optimal rate may be different than efficiency thereafter.

3) Design changes in early lots could affect rate of improvement.

4) Data could be aggregated to a higher level of the Work Breakdown Structure (WBS) and, therefore, the learning curve would be a composite of many pieces, each having its own parameters.

Actual "recurring" aircraft production data seems to support the hypothesis that more than one slope may better explain performance than the single slope. The "eyeball technique" for splitting curves was the only method available to account for these inconsistencies when it appeared that a single slope was inappropriate.

The split learning curve models remove much of the subjectivity in determining whether a single curve adequately explains performance. The statistically sound technique was developed to supply the necessary analytical tools to calculate the breakpoint(s) and to fit the "best" two or three log-log linear curves to the data. These models use a relatively new formulation of the log-log linear curve developed by Mr. Karl Berend, formerly of Air Force Systems Command. This formulation assumes continuity in the learning process with the following relationship between the curves.

1) Unit Curve: $y_u = ax^b$

2) Cumulative Total Curve: $y_T = \int_0^x (at^b)dt = (a/(b+1))x^{(b+1)}$

3) Cumulative Average Curve: $y_A = ((a/(b+1))x^b$

The advantage in this formulation, apart from being theoretically sound, lies in the ease of transition between the three curves: unit, cumulative average, and cumulative total. When describing a single curve, all three remain linear on log-log paper, hence, the equation forms remain the same. One point of caution in the use of this formulation is that the unit cost of the xth unit is derived by calculating the total cost of x units and subtracting the total cost of (x-1) units. Because learning is assumed to be continuous, the unit costs are plotted at their respective midpoints. The xth unit cost then should be plotted at the midpoint between the (x-1)st and xth unit. For more detail on this formulation, see "The Unified Linear Progress Formulation" by Mr. Berend.

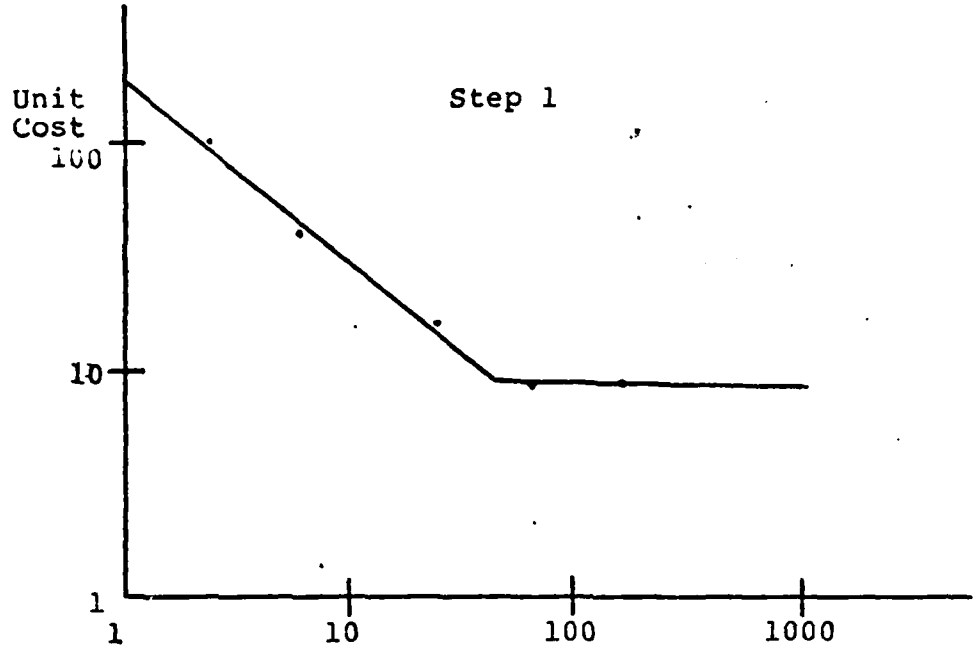
The two models use essentially the same technique for fitting the best two or three curves to the data. The technique was initially developed by Mr. John Dorsett, currently with Naval Material Command, and has been adapted to calculate the unit curve using the midpoints derived under the Unified Formulation. The methodology will be discussed for the single split (two curves); the double split being an extension of the single split.

The model first regresses the data points to find the conventional

learning curve slope and first unit cost. It uses the midpoints generated from the single curve, partitioning the data points into two sets to begin the splitting process. By forcing at least two data points to be on each curve, the model regresses all the possible sets of data points. For example, with five data points the model will regress forcing the first three data points to be on the first curve and the last two points on the second curve, as a first attempt at splitting the curve. It then regresses the first two points on the first curve and the last three points on the second curve (see Figure 1). For each data point added to the data base an additional regression is needed to exhaust all possible data point partitions. It will then recalculate the midpoints based on the new slopes and repeat the process, eventually zeroing in on a best fit.

Two kinds of phenomena could occur at the breakpoint. As illustrated in Figure 2a, a curve could simply change slopes or, as in Figure 2b, a break in continuity could occur. The model does not force either phenomenon to occur, but chooses only that combination of curves yielding the smallest residual sum of squares.

From a theoretical standpoint each of these phenomena could be explained. The continuity break could be explained by a break in the production run or a significant change in management technique at that point of production. The change in slope could be caused by reaching peak production rate, or a slowing of the production process. There is also



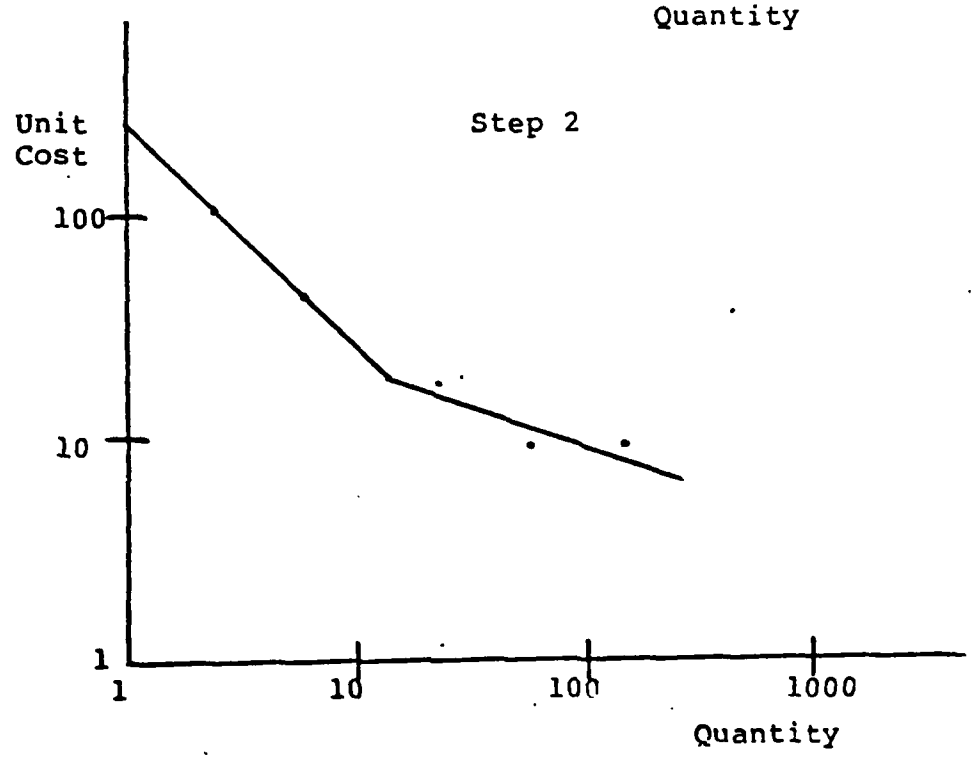



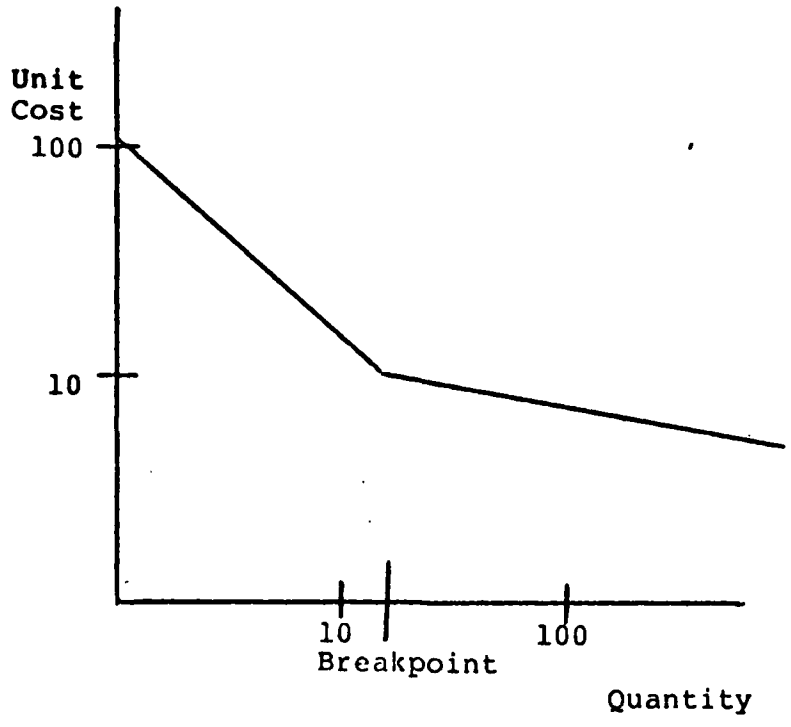

Figure 1



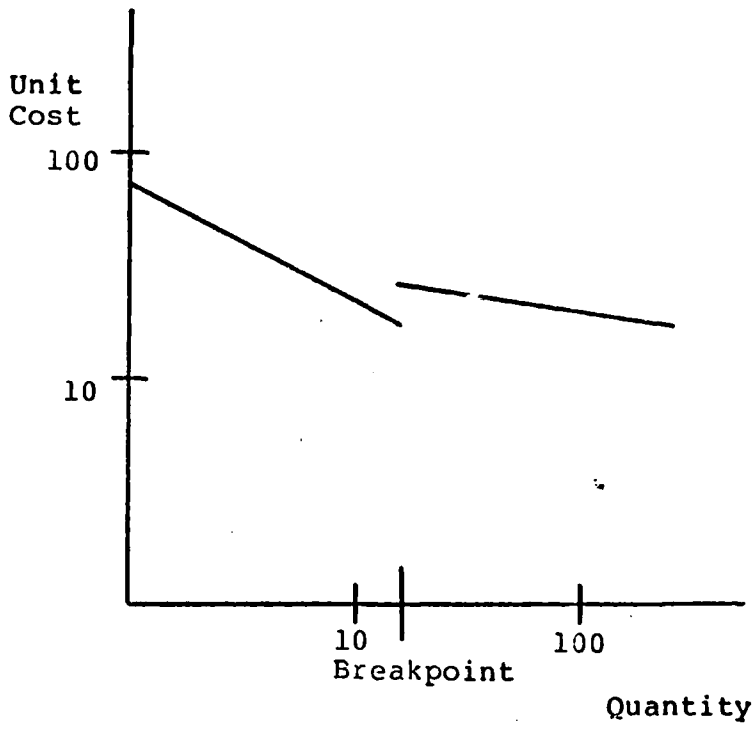
Logarithmic Grid

Single Split

Two Variations




(a)




(b)

Figure 2

Logarithmic Grid

concern that for long production runs, learning does not continue at the same rate indefinitely.

Of the two models the double split is the most powerful. It not only reacts to discontinuities in a set of data, but also closely approximates an "S" curve (which has been supported by some contractors' data). As with any statistical method, there are limitations that require the application of common sense. First of all, there are the data limitations. The split curve models require at least five data points to split a learning curve once, and at least seven data points to split the curve twice. More data points are desirable just as more than three data points are preferable when deriving a single curve. Secondly, the analyst must keep in mind that three curves will always fit the data better than two curves, and two curves will always fit better than one. Therefore, a split curve should not be chosen over a single curve on the basis of a better coefficient of determination (R2). A T-test has been incorporated into the model to aid in this determination. Thirdly, the resultant curves should make sense. The splits should have some logical reason for occurring. A break in continuity should be explainable or should serve to indicate that something out of the ordinary is occurring. When estimating the cost of a conceptual weapon system on the basis of an analogy, the exact breakpoints and slopes should make sense in terms of assumptions for the conceptual weapon system.

Equation forms and a list of statistics available from the output of

the model are listed in Appendix A. Some data and graphs for an actual aircraft system have been included in Appendix B to illustrate output and results of the computer programs. A listing of the model, currently in Basic on the Honeywell 6000, is provided in Appendix C. The computer program is currently being converted to Fortran to enhance its capabilities.

## Appendix A

The resulting set of curves can be expressed as one equation with the use of dummy variables:

### One Split

$y = (a1 + a2d1)x^{(b1 + b2d2)}$ where:

y = unit cost at x
a1= Y intercept of unit curve 1 (not first unit cost)
b1= b-value of curve 1
a1+a2= y intercept of unit curve 2 (not first unit cost)
b1+b2= b-value of curve 2
d1,d2=0 if x< breakpoint
=1 if x> breakpoint

### Two Splits

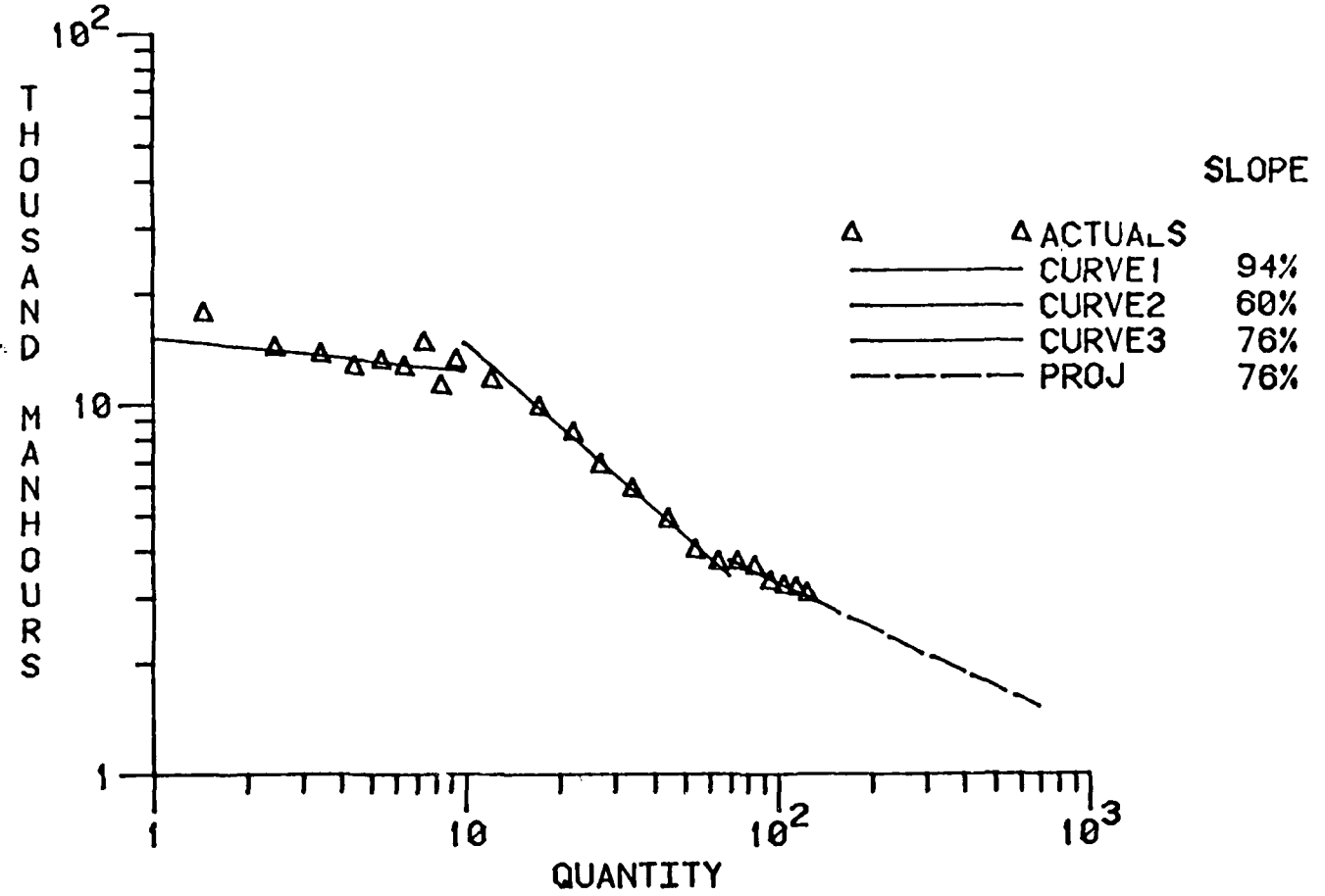
$y = (a1+a2d1+a3d2)x^{(b1+b2d3+b3d4)}$ where:

y = unit cost at x
a1=y intercept of unit curve 1
b1=b-value of unit curve 1
a1+a2=y intercept of unit curve 2
b1+b2=b-value of unit curve 2
a1+a2+a3=y intercept of unit curve 3
b1+b2+b3=b-value of unit curve 3
d1,d3=0 if x< Breakpoint 1
=1 if x> Breakpoint 1
d2,d4=0 if x< Breakpoint 2
=1 if x> Breakpoint 2

Attachment B

Program Output and Graphs

ACTUAL AIRCRAFT MANHOURS
CENTER FUSELAGE



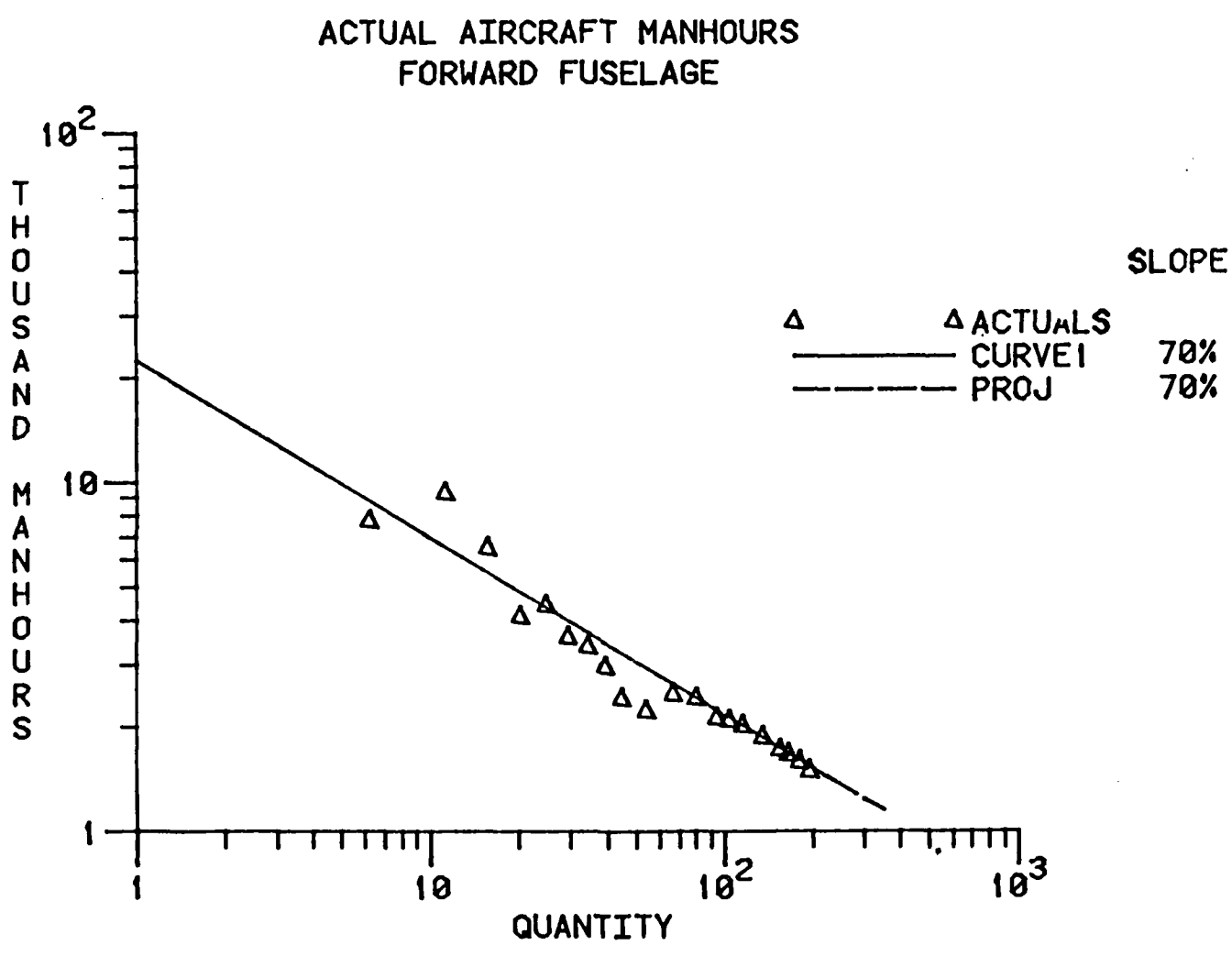
POINTS ON SECOND, NEXT 6 ON THIRD
ALL VALUES LESS THAN 10 PREDICTED FROM FIRST CURVE
ALL VALUES LESS THAN 70 BUT GREATER OR EQUAL TO 10
ARE PREDICTED FROM THE SECOND CURVE, WHILE
ALL VALUES GREATER THAN 70 PREDICTED FROM THIRD CURVE
THE PROGRAM HAS COMPLETED 2 ITERATIONS

| | T1 | Y-INTERCEPT | SLOPE | B-VALUE | B+1 |
|---|---|---|---|---|---|
| CURVE1 | 16.6365 | 15.0816 | .937 | -.093462 | .906538 |
| CURVE2 | 317.4520 | 81.1276 | .597 | -.744441 | .255559 |
| CURVE3 | 33.5706 | 20.3276 | .761 | -.394482 | .605518 |

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | %DIFF |
|---|---|---|---|---|---|---|
| 1.0 | 1 | .3500 | 17.5000 | 17.5000 | 16.6365 | -4.93 |
| 1.0 | 2 | 1.4688 | 14.0000 | 14.0000 | 14.5493 | 3.92 |
| 1.0 | 3 | 2.4816 | 13.5000 | 13.5000 | 13.8533 | 2.62 |
| 1.0 | 4 | 3.4869 | 12.5000 | 12.5000 | 13.4199 | 7.36 |
| 1.0 | 5 | 4.4899 | 13.0000 | 13.0000 | 13.1065 | .82 |
| 1.0 | 6 | 5.4917 | 12.5000 | 12.5000 | 12.8621 | 2.90 |
| 1.0 | 7 | 6.4930 | 13.0000 | 13.0000 | 12.6623 | -2.60 |
| 1.0 | 8 | 7.4939 | 14.5000 | 14.5000 | 12.4938 | -13.84 |
| 1.0 | 9 | 8.4946 | 11.0000 | 11.0000 | 12.3483 | 12.26 |
| 1.0 | 10 | 9.4952 | 13.0000 | 13.0000 | 12.2204 | -6.00 |
| 5.0 | 15 | 12.3531 | 57.5000 | 11.5000 | 12.4855 | 8.57 |
| 5.0 | 20 | 17.3956 | 48.5000 | 9.7000 | 9.6768 | -.24 |
| 5.0 | 25 | 22.4190 | 41.3000 | 8.2600 | 8.0115 | -3.01 |
| 5.0 | 30 | 27.4338 | 33.8000 | 6.7600 | 6.8936 | 1.98 |
| 10.0 | 40 | 34.7912 | 58.0000 | 5.8000 | 5.7761 | -.41 |
| 10.0 | 50 | 44.8380 | 48.0000 | 4.8000 | 4.7821 | -.37 |
| 10.0 | 60 | 54.8676 | 40.0000 | 4.0000 | 4.1148 | 2.87 |
| 10.0 | 70 | 64.8880 | 37.0000 | 3.7000 | 3.6318 | -1.84 |
| 10.0 | 80 | 74.9224 | 37.0000 | 3.7000 | 3.7033 | .09 |
| 10.0 | 90 | 84.9316 | 36.0000 | 3.6000 | 3.5245 | -2.10 |
| 10.0 | 100 | 94.9388 | 33.0000 | 3.3000 | 3.3730 | 2.21 |
| 10.0 | 110 | 104.9447 | 32.0000 | 3.2000 | 3.2423 | 1.32 |
| 10.0 | 120 | 114.9495 | 31.5000 | 3.1500 | 3.1279 | -.70 |
| 10.0 | 130 | 124.9534 | 30.5000 | 3.0500 | 3.0266 | -.77 |

PREDICTIONS

| LOT | CUM | UNIT | TOT LOT | LOT AVG | CUM TOT | CUM AVG |
|---|---|---|---|---|---|---|
| 10.0 | 10 | 12.2204 | 134.1524 | 13.4152 | 134.15 | 13.4152 |
| 10.0 | 20 | 8.8895 | 110.8117 | 11.0812 | 244.96 | 12.2482 |
| 10.0 | 30 | 6.5313 | 74.5258 | 7.4526 | 319.49 | 10.6497 |
| 10.0 | 40 | 5.2555 | 57.7610 | 5.7761 | 377.25 | 9.4313 |
| 10.0 | 50 | 4.4427 | 47.8206 | 4.7821 | 425.07 | 8.5014 |
| 10.0 | 60 | 3.8739 | 41.1481 | 4.1148 | 466.22 | 7.7703 |
| 10.0 | 70 | 3.4508 | 36.3177 | 3.6318 | 502.54 | 7.1791 |
| 10.0 | 80 | 3.6177 | 37.0327 | 3.7033 | 539.57 | 6.7446 |
| 10.0 | 90 | 3.4525 | 35.2454 | 3.5245 | 574.82 | 6.3868 |
| 10.0 | 100 | 3.3112 | 33.7303 | 3.3730 | 608.55 | 6.0855 |
| 200.0 | 300 | 2.1438 | 515.7002 | 2.5781 | 1124.25 | 3.7475 |


ACTUAL AIRCRAFT MANHOURS
FORWARD FUSELAGE
THOUSAND MANHOURS
$10^2$
10
1
1
10
$10^2$
$10^3$
QUANTITY
SLOPE
ACTUALS
CURVE1 70%
PROJ 70%

FORWARD FUSELAGE

UNIFIED LOG-LINEAR PROGRESS CURVE FORMULATION-ALL CURVES ARE LINEAR
LINEAR LEAST SQUARES ANALYSIS OF UNIT CURVE-NTH UNITS AT MIDPOINTS
SLOPES: PERCENT = .704; B=-.50638;B+1= .49362;-1/B+1=-2.02586
FIRST UNIT COST 45.11578; Y-INTERCEPT OF LIN UNIT CURVE= 22.26997
R= .972842; R-SQUARED= .946421; RBAR-SQUARED= .943601

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | % DIFF |
|---|---|---|---|---|---|---|
| 5.0 | 9 | 6.2489 | 38.5000 | 7.7000 | 8.8052 | 14.35 |
| 5.0 | 14 | 11.3619 | 46.0000 | 9.2000 | 6.5052 | -29.29 |
| 4.0 | 18 | 15.9370 | 25.8000 | 6.4500 | 5.4808 | -15.03 |
| 5.0 | 23 | 20.4232 | 20.5000 | 4.1000 | 4.8339 | 17.90 |
| 4.0 | 27 | 24.9598 | 17.6000 | 4.4000 | 4.3670 | -.75 |
| 5.0 | 32 | 29.4467 | 20.5000 | 4.1000 | 4.0163 | -2.04 |
| 5.0 | 37 | 34.4545 | 17.7500 | 3.5500 | 3.7093 | 4.49 |
| 5.0 | 42 | 39.4602 | 16.7500 | 3.3500 | 3.4630 | 3.37 |
| 6.0 | 48 | 44.9497 | 17.7000 | 2.9500 | 3.2420 | 9.90 |
| 13.0 | 61 | 54.3047 | 31.2000 | 2.4000 | 2.9460 | 22.75 |
| 12.0 | 73 | 66.8648 | 26.4000 | 2.2000 | 2.6514 | 20.52 |
| 16.0 | 89 | 80.8012 | 39.2000 | 2.4500 | 2.4090 | -1.67 |
| 10.0 | 99 | 93.9331 | 24.0000 | 2.4000 | 2.2321 | -6.99 |
| 11.0 | 110 | 104.4273 | 23.1000 | 2.1000 | 2.1156 | .74 |
| 10.0 | 120 | 114.9454 | 20.5000 | 2.0500 | 2.0152 | -1.70 |
| 30.0 | 150 | 134.5803 | 60.0000 | 2.0000 | 1.8606 | -6.97 |
| 10.0 | 160 | 154.9596 | 18.5000 | 1.8500 | 1.7323 | -6.36 |
| 10.0 | 170 | 164.9619 | 17.0000 | 1.7000 | 1.6783 | -1.27 |
| 20.0 | 190 | 179.8603 | 33.0000 | 1.6500 | 1.6064 | -2.64 |
| 10.0 | 200 | 194.9680 | 15.7500 | 1.5750 | 1.5421 | -2.09 |
| 50.0 | 250 | 224.3005 | 73.7500 | 1.4750 | 1.4365 | -2.61 |

SPLIT LEARNING CURVES

EQUATION FORM Y=e ^(A1+A2*DUM1)*X^ (B1+B2*DUM1)

| VARIABLE | COEFFICIENT | T-STATISTIC |
|---|---|---|
| A1 | 2.358636 | 7.080 |
| A2 | .468805 | 1.311 |
| B1 | -.135041 | -.965 |
| B2 | -.312569 | -2.184 |

THE ABSOLUTE VALUE OF THE T-STATISTIC FOR A2 AND/OR
B2 DOES NOT EXCEED 2.11 THESE VARIABLES ARE NOT
SIGNIFICANT AT THE 95% CONFIDENCE LIMIT AND THEREFORE,
A SPLIT LEARNING CURVE DOES NOT EXIST.

R-SQUARED .9736378
RBAR-SQUARED .9689857
RESIDUAL SUM OF SQUARES .1468594

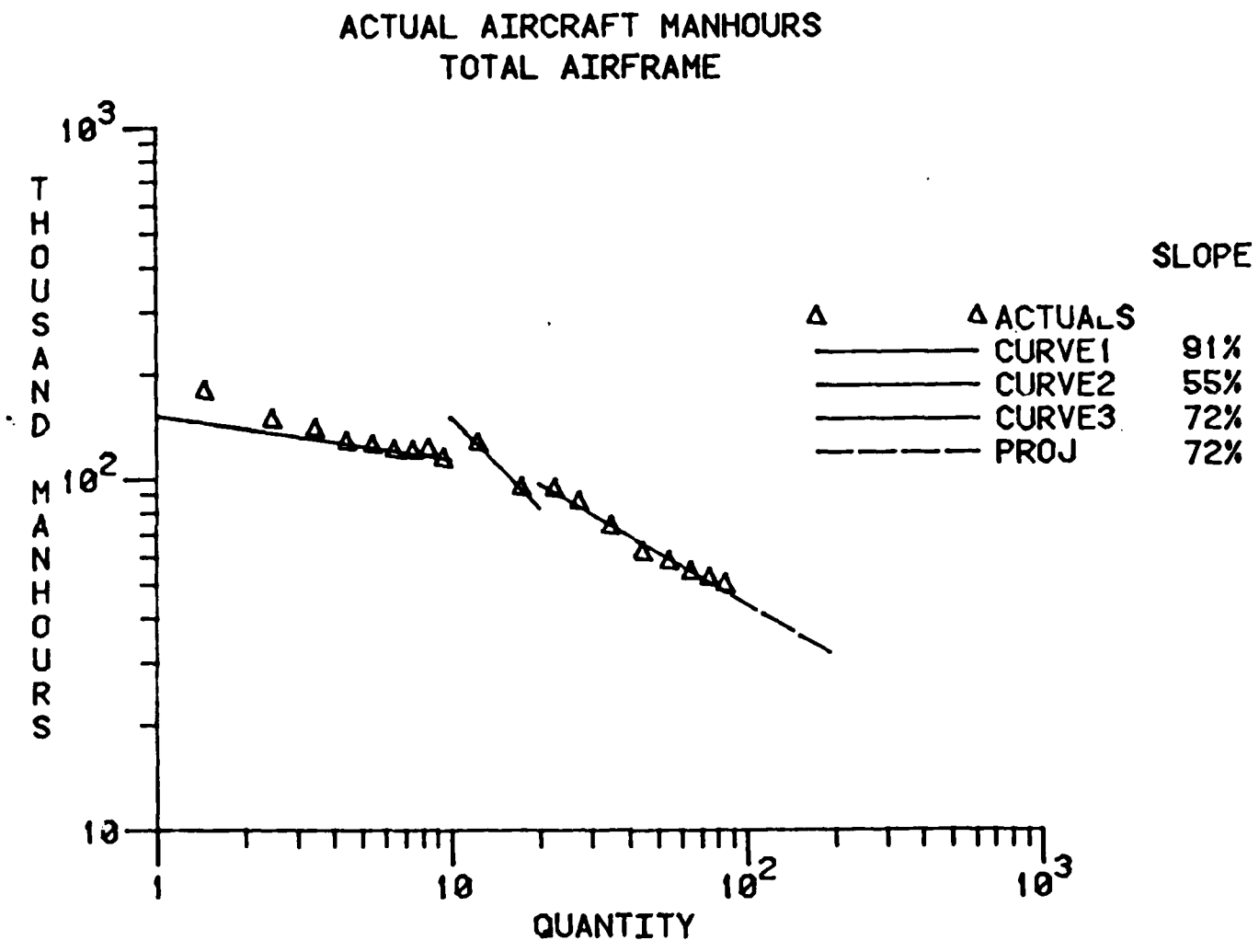
FIRST 3 POINTS ON FIRST CURVE, REMAINDER ON SECOND
ALL VALUES LESS THAN 18 PREDICTED FROM FIRST CURVE
ALL VALUES GREATER THAN 18 PREDICTED FROM SECOND CURVE

| | T1 | Y-INTERCEPT | SLOPE | B-VALUE | B+1 |
|---|---|---|---|---|---|
| CURVE1 | 12.2278 | 10.5765 | .911 | -.135041 | .864959 |
| CURVE2 | 30.5983- | 16.9021 | .733 | -.447611 | .552389 |

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | % DIFF |
|---|---|---|---|---|---|---|
| 5.0 | 9 | 6.3115 | 38.5000 | 7.7000 | 8.2469 | 7.10 |
| 5.0 | 14 | 11.3961 | 46.0000 | 9.2000 | 7.6144 | -17.23 |
| 4.0 | 18 | 15.9525 | 25.8000 | 6.4500 | 7.2763 | 12.81 |
| 5.0 | 23 | 20.4262 | 20.5000 | 4.1000 | 4.3801 | 6.83 |
| 4.0 | 27 | 24.9613 | 17.6000 | 4.4000 | 4.0041 | -9.00 |
| 5.0 | 32 | 29.4488 | 20.5000 | 4.1000 | 3.7185 | -9.30 |
| 5.0 | 37 | 34.4562 | 17.7500 | 3.5500 | 3.4661 | -2.36 |
| 5.0 | 42 | 39.4618 | 16.7500 | 3.3500 | 3.2619 | -2.63 |
| 6.0 | 48 | 44.9517 | 17.7000 | 2.9500 | 3.0772 | 4.31 |
| 13.0 | 61 | 54.3123 | 31.2000 | 2.4000 | 2.8274 | 17.81 |
| 12.0 | 73 | 66.8701 | 26.4000 | 2.2000 | 2.5760 | 17.09 |
| 16.0 | 89 | 80.8089 | 39.2000 | 2.4500 | 2.3667 | -3.40 |
| 10.0 | 99 | 93.9358 | 24.0000 | 2.4000 | 2.2125 | -7.81 |
| 11.0 | 110 | 104.4302 | 23.1000 | 2.1000 | 2.1101 | .48 |
| 10.0 | 120 | 114.9476 | 20.5000 | 2.0500 | 2.0213 | -1.40 |
| 30.0 | 150 | 134.5966 | 60.0000 | 2.0000 | 1.8835 | -5.83 |
| 10.0 | 160 | 154.9611 | 18.5000 | 1.8500 | 1.7684 | -4.41 |
| 10.0 | 170 | 164.9635 | 17.0000 | 1.7000 | 1.7196 | 1.15 |
| 20.0 | 190 | 179.8659 | 33.0000 | 1.6500 | 1.6543 | .26 |
| 10.0 | 200 | 194.9693 | 15.7500 | 1.5750 | 1.5956 | 1.31 |
| 50.0 | 250 | 224.3277 | 73.7500 | 1.4750 | 1.4985 | 1.59 |

PREDICTIONS

| LOT | CUM | UNIT | TOT LOT | LOT AVG | CUM TOT | CUM AVG |
|---|---|---|---|---|---|---|
| 10.0 | 10 | 7.8044 | 89.5996 | 8.9600 | 89.60 | 8.9600 |
| 10.0 | 20 | 4.4724 | 68.4244 | 6.8424 | 158.02 | 7.9012 |
| 10.0 | 30 | 3.7158 | 40.1896 | 4.0190 | 198.21 | 6.6071 |
| 10.0 | 40 | 3.2606 | 34.4957 | 3.4496 | 232.71 | 5.8177 |
| 10.0 | 50 | 2.9473 | 30.7984 | 3.0798 | 263.51 | 5.2702 |
| 10.0 | 60 | 2.7143 | 28.1401 | 2.8140 | 291.65 | 4.8608 |
| 10.0 | 70 | 2.5319 | 26.1060 | 2.6106 | 317.75 | 4.5393 |
| 10.0 | 80 | 2.3841 | 24.4823 | 2.4482 | 342.24 | 4.2780 |
| 10.0 | 90 | 2.2609 | 23.1460 | 2.3146 | 365.38 | 4.0598 |
| 10.0 | 100 | 2.1562 | 22.0202 | 2.2020 | 387.40 | 3.8740 |
| 200.0 | 300 | 1.3167 | 325.0776 | 1.6254 | 712.48 | 2.3749 |


ACTUAL AIRCRAFT MANHOURS
TOTAL AIRFRAME
THOUSAND MANHOURS
$10^3$
$10^2$
10
1
10
$10^2$
$10^3$
QUANTITY
SLOPE
ACTUALS
CURVE1 91%
CURVE2 55%
CURVE3 72%
PROJ 72%

TOTAL AIRFRAME

UNIFIED LOG-LINEAR PROGRESS CURVE FORMULATION-ALL CURVES ARE LINEAR
LINEAR LEAST SQUARES ANALYSES OF UNIT CURVE-NTH UNITS AT MIDPOINTS
SLOPES; PERCENT= .842; B=-.24726; B+1= .7527;-1/B+1=-1.3285
FIRST UNIT COST 232.62415; Y-INT. OF LIN UNIT CURVE 175.10654

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | %DIFF |
|---|---|---|---|---|---|---|
| 1.0 | 1 | .3170 | 177.0000 | 177.0000 | 232.6242 | 31.43 |
| 1.0 | 2 | 1.4644 | 146.0000 | 146.0000 | 159.3464 | 9.14 |
| 1.0 | 3 | 2.4790 | 137.5000 | 137.5000 | 139.8990 | 1.74 |
| 1.0 | 4 | 3.4851 | 126.0000 | 126.0000 | 128.5989 | 2.06 |
| 1.0 | 5 | 4.4884 | 123.0000 | 123.0000 | 120.8005 | -1.79 |
| 1.0 | 6 | 5.4905 | 120.0000 | 120.0000 | 114.9287 | -4.23 |
| 1.0 | 7 | 6.4920 | 119.0000 | 119.0000 | 110.2649 | -7.34 |
| 1.0 | 8 | 7.4931 | 121.0000 | 121.0000 | 106.4236 | -12.05 |
| 1.0 | 9 | 8.4939 | 119.0000 | 119.0000 | 103.1753 | -13.30 |
| 1.0 | 10 | 9.4945 | 113.0000 | 113.0000 | 100.3730 | -11.17 |
| 5.0 | 15 | 12.3951 | 621.0000 | 124.2000 | 93.9703 | -24.34 |
| 5.0 | 20 | 17.4254 | 464.0000 | 92.8000 | 86.3800 | -6.92 |
| 5.0 | 25 | 22.4421 | 460.0000 | 92.0000 | 81.1418 | -11.80 |
| 5.0 | 30 | 27.4527 | 425.0000 | 85.0000 | 77.1977 | -9.18 |
| 10.0 | 40 | 34.8508 | 727.0000 | 72.7000 | 72.7749 | .10 |
| 10.0 | 50 | 44.8842 | 613.0000 | 61.3000 | 68.3617 | 11.52 |
| 10.0 | 60 | 54.9053 | 575.0000 | 57.5000 | 65.0389 | 13.11 |
| 10.0 | 70 | 64.9199 | 537.0000 | 53.7000 | 62.3996 | 16.20 |
| 10.0 | 80 | 74.9307 | 515.0000 | 51.5000 | 60.2258 | 16.94 |
| 10.0 | 90 | 84.9389 | 497.0000 | 49.7000 | 58.3875 | 17.48 |

SPLIT LEARNING CURVES

EQUATION FORM Y=e ^(A1+A2*DUM1+A3*DUM2)*X^(B1+B2*DUM1+B3*DUM2)

| VARIABLE | COEFFICIENT | T-STATISTIC |
|---|---|---|
| A1 | 5.029462 | 361.49 |
| A2 | 1.929649 | 6.62 |
| A3 | -.954209 | -3.16 |
| B1 | -.130789 | -15.17 |
| B2 | -.719631 | -6.62 |
| B3 | .368841 | 3.35 |

IF ABSOLUTE VALUE OF T-STATISTIC EXCEEDS 2.145
FOR THE DUMMY VARIABLES A2,A3,B2,AND B3, THEN THESE VARIABLES
ARE SIGNIFICANT AT 95% CONFIDENCE LIMIT AND THERE EXISTS
A TWICE SPLIT LEARNING CURVE

R-SQUARED .9960643
RESIDUAL SUM OF SQUARES .0110168

FIRST 10 POINTS ON FIRST CURVE, NEXT 2
POINTS ON SECOND, NEXT 8 ON THIRD
ALL VALUES LESS THAN 10 PREDICTED FROM FIRST CURVE
ALL VALUES LESS THAN 20 BUT GREATER OR EQUAL TO 10
ARE PREDICTED FROM THE SECOND CURVE, WHILE
ALL VALUES GREATER THAN 20 PREDICTED FROM THIRD CURVE
THE PROGRAM HAS COMPLETED 2 ITERATIONS

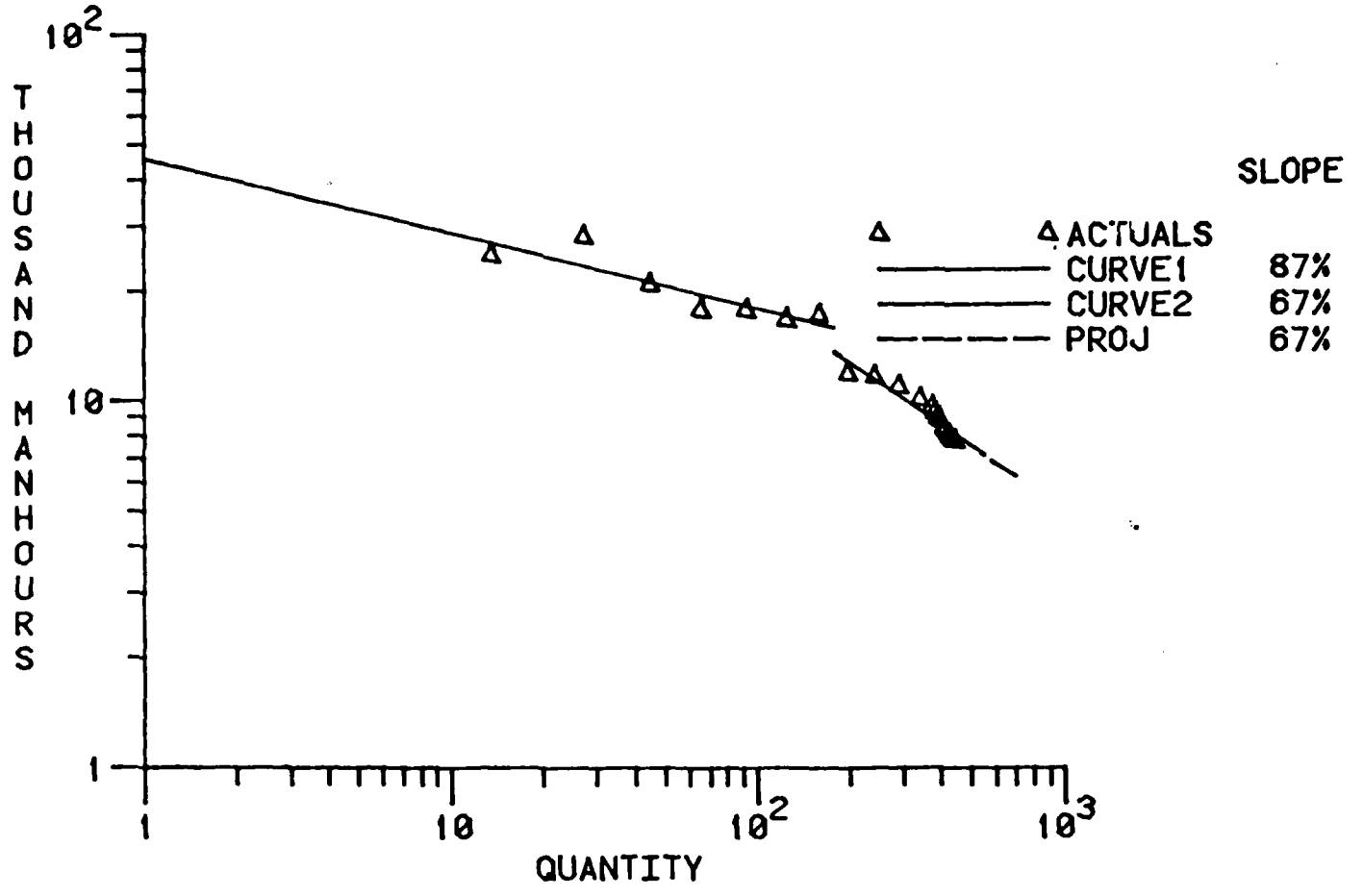
| | T1 | Y-INTERCEPT | SLOPE | B-VALUE | B+1 |
|---|---|---|---|---|---|
| CURVE1 | 175.8500 | 152.8508 | .913 | -.130789 | .869211 |
| CURVE2 | ******** | ******** | .555 | -.850420 | .149580 |
| CURVE3 | 782.0105 | 405.4110 | .716 | -.481579 | .518421 |

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | %DIFF |
|---|---|---|---|---|---|---|
| 1.0 | 1 | .3424 | 177.0000 | 177.0000 | 175.8500 | -.65 |
| 1.0 | 2 | 1.4678 | 146.0000 | 146.0000 | 145.3688 | -.43 |
| 1.0 | 3 | 2.4810 | 137.5000 | 137.5000 | 135.7236 | -1.29 |
| 1.0 | 4 | 3.4865 | 126.0000 | 126.0000 | 129.8164 | 3.03 |
| 1.0 | 5 | 4.4895 | 123.0000 | 123.0000 | 125.5935 | 2.11 |
| 1.0 | 6 | 5.4914 | 120.0000 | 120.0000 | 122.3278 | 1.94 |
| 1.0 | 7 | 6.4927 | 119.0000 | 119.0000 | 119.6771 | .57 |
| 1.0 | 8 | 7.4937 | 121.0000 | 121.0000 | 117.4538 | -2.93 |
| 1.0 | 9 | 8.4945 | 119.0000 | 119.0000 | 115.5439 | -2.90 |
| 1.0 | 10 | 9.4950 | 113.0000 | 113.0000 | 113.8733 | .77 |
| 5.0 | 15 | 12.3441 | 621.0000 | 124.2000 | 124.1949 | -.00 |
| 5.0 | 20 | 17.3893 | 464.0000 | 92.8000 | 92.7992 | -.00 |
| 5.0 | 25 | 22.4312 | 460.0000 | 92.0000 | 90.6471 | -1.47 |
| 5.0 | 30 | 27.4438 | 425.0000 | 85.0000 | 82.2568 | -3.23 |
| 10.0 | 40 | 34.8227 | 727.0000 | 72.7000 | 73.3445 | .89 |
| 10.0 | 50 | 44.8624 | 613.0000 | 61.3000 | 64.9209 | 5.91 |
| 10.0 | 60 | 54.8875 | 575.0000 | 57.5000 | 58.9118 | 2.46 |
| 10.0 | 70 | 64.9049 | 537.0000 | 53.7000 | 54.3428 | 1.20 |
| 10.0 | 80 | 74.9176 | 515.0000 | 51.5000 | 50.7150 | -1.52 |
| 10.0 | 90 | 84.9273 | 497.0000 | 49.7000 | 47.7428 | -3.94 |

PREDICTIONS

| LOT | CUM | UNIT | TOT LOT | LOT AVG | CUM TOT | CUM AVG |
|---|---|---|---|---|---|---|
| 10.0 | 10 | 113.8733 | 1301.2280 | 130.1228 | 1301.23 | 130.1228 |
| 10.0 | 20 | 84.1992 | 1084.9706 | 108.4971 | 2386.20 | 119.3099 |
| 10.0 | 30 | 79.4467 | 864.5199 | 86.4520 | 3250.72 | 108.3573 |
| 10.0 | 40 | 69.0267 | 733.4452 | 73.3445 | 3984.16 | 99.6041 |
| 10.0 | 50 | 61.9178 | 649.2089 | 64.9209 | 4633.37 | 92.6674 |
| 10.0 | 60 | 56.6669 | 589.1182 | 58.9118 | 5222.49 | 87.0415 |
| 10.0 | 70 | 52.5821 | 543.4276 | 54.3428 | 5765.92 | 82.3703 |
| 10.0 | 80 | 49.2858 | 507.1499 | 50.7150 | 6273.07 | 78.4134 |
| 10.0 | 90 | 46.5522 | 477.4279 | 47.7428 | 6750.50 | 75.0055 |
| 10.0 | 100 | 44.2372 | 452.4907 | 45.2491 | 7202.99 | 72.0299 |
| 200.0 | 300 | 26.0203 | 6532.9906 | 32.6650 | 13735.98 | 45.7866 |

ACTUAL AIRCRAFT MANHOURS
TOTAL FABRICATION



TOTAL FABRICATION

UNIFIED LOG-LINEAR PROGRESS CURVE FORMULATION-ALL CURVES ARE LINEAR
LINEAR LEAST SQUARES ANALYSIS OF UNIT CURVE-NTH UNITS AT MIDPOINTS
SLOPES: PERCENT = .766; B=-.38376;B+1= .61624;-1/B+1=-1.62276
FIRST UNIT COST 145.77862; Y-INTERCEPT OF LIN UNIT CURVE= 89.83397
R= .956506; R-SQUARED= .914904; RBAR-SQUARED= .910425

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | % DIFF |
|---|---|---|---|---|---|---|
| 12.6 | 21 | 13.6263 | 312.0350 | 24.7647 | 32.9691 | 33.13 |
| 14.6 | 35 | 27.4519 | 408.1040 | 27.9523 | 25.1981 | -9.85 |
| 19.8 | 55 | 44.5928 | 411.9450 | 20.8053 | 20.9176 | .54 |
| 22.8 | 78 | 65.9453 | 402.9020 | 17.6711 | 18.0012 | 1.87 |
| 30.5 | 108 | 92.4698 | 540.7600 | 17.7298 | 15.8110 | -10.82 |
| 34.5 | 143 | 125.0009 | 573.3130 | 16.6178 | 14.0838 | -15.25 |
| 35.8 | 179 | 160.2388 | 616.9750 | 17.2339 | 12.8035 | -25.71 |
| 40.9 | 220 | 198.5642 | 485.8820 | 11.8798 | 11.7920 | -.74 |
| 45.9 | 265 | 241.9479 | 532.2040 | 11.5949 | 10.9308 | -5.73 |
| 49.9 | 315 | 289.8547 | 546.0040 | 10.9420 | 10.1987 | -6.79 |
| 49.7 | 365 | 339.7309 | 503.0280 | 10.1213 | 9.5958 | -5.19 |
| 9.1 | 374 | 369.5377 | 87.1420 | 9.5760 | 9.2910 | -2.98 |
| 9.4 | 384 | 378.7855 | 86.9690 | 9.2520 | 9.2033 | -.53 |
| 9.3 | 393 | 388.1382 | 83.3030 | 8.9573 | 9.1176 | 1.79 |
| 9.7 | 403 | 397.6349 | 84.8750 | 8.7500 | 9.0334 | 3.24 |
| 7.1 | 410 | 406.0431 | 60.1170 | 8.4672 | 8.9611 | 5.83 |
| 6.4 | 416 | 412.7954 | 53.0480 | 8.2887 | 8.9046 | 7.43 |
| 7.2 | 423 | 419.5934 | 58.2470 | 8.0899 | 8.8490 | 9.38 |
| 7.2 | 430 | 426.7933 | 57.1410 | 7.9362 | 8.7914 | 10.77 |
| 6.1 | 437 | 433.4460 | 47.6180 | 7.8062 | 8.7393 | 11.95 |
| 8.6 | 445 | 440.7913 | 66.6660 | 7.7519 | 8.6832 | 12.01 |

SPLIT LEARNING CURVES

EQUATION FORM Y=e^(A1+A2*DUM1)*X^(B1+B2*DUM1)

| VARIABLE | COEFFICIENT | T-STATISTIC |
|---|---|---|
| A1 | 3.826407 | 28.278 |
| A2 | 1.773740 | 3.571 |
| B1 | -.204730 | -6.249 |
| B2 | -.370901 | -4.236 |

THE ABSOLUTE VALUE OF THE T-STATISTIC FO A2 AND B2
EXCEEDS 2.11 THESE VARIABLES, THEN, ARE
SIGNIFICANT AT THE 95% CONFIDENCE LIMIT AND THERE EXISTS
A SPLIT LEARNING CURVE

R-SQUARED .975408
RBAR-SQUARED .9710682
RESIDUAL SUM OF SQUARES .0832367

FIRST 7 POINTS ON FIRST CURVE, REMAINDER ON SECOND
ALL VALUES LESS THAN 178.6 PREDICTED FROM FIRST CURVE
ALL VALUES GREATER THAN 178.6 PREDICTED FROM SECOND CURVE

| | T1 | Y-INTERCEPT | SLOPE | B-VALUE | B+1 |
|---|---|---|---|---|---|
| CURVE1 | 57.7132 | 45.8076 | .868 | -.204730 | .795269 |
| CURVE2 | 637.3261 | 270.4616 | .671 | -.575631 | .424369 |

| LOT | CUM | X(M) | ACTUAL LOT TOT | ACTUAL LOT AVG | CALC LOT AVG | % DIFF |
|---|---|---|---|---|---|---|
| 12.6 | 21 | 13.7150 | 312.0350 | 24.7647 | 26.8517 | 8.43 |
| 14.6 | 35 | 27.5102 | 408.1040 | 27.9523 | 23.2853 | -16.70 |
| 19.8 | 55 | 44.6587 | 411.9450 | 20.8053 | 21.0865 | 1.35 |
| 22.8 | 78 | 66.0043 | 402.9020 | 17.6711 | 19.4656 | 10.15 |
| 30.5 | 108 | 92.5450 | 540.7600 | 17.7298 | 18.1642 | 2.45 |
| 34.5 | 143 | 125.[illegible] | 573.3130 | 16.6178 | 17.0780 | 2.77 |
| 35.8 | 179 | 160.2987 | 616.9750 | 17.2339 | 16.2320 | -5.81 |
| 40.9 | 220 | 198.4968 | 485.8820 | 11.8798 | 12.8661 | 8.30 |
| 45.9 | 265 | 241.8782 | 532.2040 | 11.5949 | 11.4824 | -.97 |
| 49.9 | 315 | 289.7858 | 546.0040 | 10.9420 | 10.3480 | -5.43 |
| 49.7 | 365 | 339.6728 | 503.0280 | 10.1213 | 9.4438 | -6.69 |
| 9.1 | 374 | 369.5354 | 87.1420 | 9.5760 | 8.9967 | -6.05 |
| 9.4 | 384 | 378.7838 | 86.9690 | 9.2520 | 8.8696 | -4.13 |
| 9.3 | 393 | 388.1358 | 83.3030 | 8.9573 | 8.7459 | -2.36 |
| 9.7 | 403 | 397.6348 | 84.8750 | 8.7500 | 8.6251 | -1.43 |
| 7.1 | 410 | 406.0412 | 60.1170 | 8.4672 | 8.5218 | .65 |
| 6.4 | 416 | 412.7948 | 53.0480 | 8.2887 | 8.4413 | 1.84 |
| 7.2 | 423 | 419.5921 | 58.2470 | 8.0899 | 8.3623 | 3.37 |
| 7.2 | 430 | 426.7907 | 57.1410 | 7.9362 | 8.2808 | 4.34 |
| 6.1 | 437 | 433.4451 | 47.6180 | 7.8062 | 8.2074 | 5.14 |
| 8.6 | 445 | 440.7902 | 66.6660 | 7.7519 | 8.1284 | 4.86 |

PREDICTIONS

| LOT | CUM | UNIT | TOT LOT | LOT AVG | CUM TOT | CUM AVG |
|---|---|---|---|---|---|---|
| 10.0 | 10 | 28.9514 | 360.2009 | 36.0201 | 360.20 | 36.0201 |
| 10.0 | 20 | 24.9857 | 264.8923 | 26.4892 | 625.09 | 31.2547 |
| 10.0 | 30 | 22.9550 | 237.8551 | 23.7855 | 862.95 | 28.7649 |
| 10.0 | 40 | 21.6232 | 221.8394 | 22.1839 | 1084.79 | 27.1197 |
| 10.0 | 50 | 20.6469 | 210.6434 | 21.0643 | 1295.43 | 25.9086 |
| 10.0 | 60 | 19.8835 | 202.1307 | 20.2131 | 1497.56 | 24.9594 |
| 10.0 | 70 | 19.2610 | 195.3155 | 19.5316 | 1692.88 | 24.1840 |
| 10.0 | 80 | 18.7381 | 189.6649 | 18.9665 | 1882.54 | 23.5318 |
| 10.0 | 90 | 18.2891 | 184.8590 | 18.4859 | 2067.40 | 22.9711 |
| 10.0 | 100 | 17.8968 | 180.6919 | 18.0692 | 2248.09 | 22.4809 |
| 200.0 | 300 | 10.1534 | 2734.1233 | 13.6706 | 4982.22 | 16.6074 |

# Appendix C

## Program Listings

One Split

```
10 DIM T(30)
12 FOR I=1 TO 30
14 READ T(I)
16 NEXT I
17 DATA 12.706,4.303,3.182,2.776,2.571,2.447,2.365,2.306,2.262,2.228
18 DATA 2.201,2.179,2.16,2.145,2.131,2.12,2.11,2.101,2.093,2.086
19 DATA 2.08,2.074,2.069,2.064,2.06,2.056,2.052,2.048,2.045,2.042
40 REM    SPLIT LEARNING CURVE PROGRAM
41 REM     AT LEAST FIVE AND PREFERABLY MORE DATA POINTS NEEDED
42 REM     THIS PROGRAM FIRST REGRESSES DATA TO FIT A LOG-LOG LINEAR
43 REM      UNIT CURVE ACCORDING TO THE UNIFIED LINEAR PROGRESS CURVE
44 REM     FORMULATION.  IT PLOTS ALL UNIT COSTS AT THEIR RESPECTIVE
45 REM    MIDPOINTS, INCLUDING LOTS OF ONE.  IT THEN FITS THE BEST TWO
46 REM     LOG-LOG LINEAR CURVES TO THE SET OF DATA, CREATING A SPLIT
47 REM     CURVE.
50 REM    USE DATA STATEMENTS BETWEEN LINES 100 AND 1000 TO INPUT DATA
52 REM    ENTER THE NUMBER OF DATA POINTS
55 REM     FIRST PUT IN ALL LOT COST OR HOURLY DATA.  NEXT ENTER IN SETS,
56 REM    THEIR RESPECTIVE CUMULATIVE BEGINNING POINTS AND END POINTS
57 REM    OF THE LOTS.  THIRDLY, INPUT THE CUMULATIVE QUANTITIES FROM
65 REM    WHICH YOU WISH TO PREDICT
70 REM    DO NOT RESAVE !!!!!!!!!!!!!!!!
72 REM    EXAMPLE:  100 DATA 9
74 REM              110 DATA 6.53,6.31,6.14,5.99,5.87,5.59,5.35,5.15,4.96
76 REM              120 DATA 0,50,50,100,100,150,150,200,200,250,250,300
77 REM              121 DATA 300,350,350,400,400,450
78 REM              130 DATA 40,60,80,100,500,1000
80 DIM A7(50),A8(50),Q(50),M(50),Z(50,2),Z1(2,50),Z2(2,2)
82 DIM Z3(2,2),Z4(2,50),B7(2)
84 DIM P(7),R(40,10)
86 DIM E6(50,50),E7(50,50),F1(50),F3(1,50)
88 DIM P1(2),C5(50),C6(50)
90 DIM L(50),Q1(50)
91 DIM R1(1,50)
92 DIM Q2(50)
93 DIM Q3(50)
94 DIM X1(50,50),X4(50,50),Y1(50,50),Y(50),X(50,4),D(50)
100 DATA 15
110 DATA 496.585,397.268,366.787,348.296,335.162,325.054,316.882,310.051
111 DATA 304.199,294.926,282.912,272.419,263.146,254.867,247.415
120 DATA 0,100,100,200,200,300,300,400,400,500,500,600,600,700
121 DATA 700,800,800,900,900,1000,1000,1100,1100,1200,1200,1300,1300
122 DATA 1400,1400,1500
```

```
130 DATA 1,500,1000,1500,1800
500 READ N
505 FILES M2;M3
510 FOR I=1 TO N
520 READ A7(I)
530 NEXT I
535 SCRATCH #2
540 FOR I=1 TO N
550 READ L(I),Q(I)
552 Q1(I)=Q(I)-L(I)
560 A8(I)=A7(I)/Q1(I)
565 A8(I)=LOG(A8(I))
567 WRITE #2,A8(I)
570 NEXT I
572 FOR I=1 TO 1000
573 READ Q2(I)
574 IF Q2(I)=9010000001 THEN 580
576 NEXT I
580 S1=0
590 FOR I=1 TO N
596 RESTORE #2
597 MAT READ #2,Y(N)
610 S1=S1+Y(I)
612 NEXT I
615 S1=S1**2
620 S1=S1/N
630 B5=-.9
640 FOR I=1 TO N
650 M(I)=((Q(I)**(B5+1)-L(I)**(B5+1))/((Q(I)-L(I))*(B5+1)))**(1/B5)
660 Z(I,2)=M(I)
670 Z(I,2)=LOG(Z(I,2))
680 Z(I,1)=1
690 NEXT I
691 SCRATCH #2
692 FOR I=1 TO N
693 FOR J=1 TO 2
694 WRITE #2,Z(I,J)
695 NEXT J
696 NEXT I
697 RESTORE #2
698 MAT READ #2,Z(N,2)
700 MAT Z1=TRN(Z)
710 MAT Z2=Z1*Z
720 MAT Z3=INV(Z2)
730 MAT Z4=Z3*Z1
740 MAT B7=Z4*Y
```

```
750 IF ABS(B7(2)-B5)<ABS(.0000005) GO TO 780
760 B5=B7(2)
770 GO TO 640
780 MAT B8=TRN(B7)
782 MAT R1=B8*Z1
784 MAT R3=R1*Y
786 MAT Y1=TRN(Y)
788 MAT Y2=Y1*Y
795 SCRATCH #2
796 MAT WRITE #2,Y2,R3
797 RESTORE #2
798 MAT READ #2,P1
810 R2=(P1(2)-S1)/(P1(1)-S1)
812:   UNIFIED LOG-LINEAR PROGRESS CURVE FORMULATION-ALL CURVES ARE LINEAR
814:    LINEAR LEAST SQUARES ANALYSIS OF UNIT CURVE-NTH UNITS AT MIDPOINTS
816:   SLOPES: PERCENT =###.###; B=#.#####;B+1=#.#####;-1/B+1=##.#####
817:                                ACTUAL     ACTUAL     CALC
818:  FIRST UNIT COST ######.#####; Y-INTERCEPT OF LIN UNIT CURVE=####.#####
820: R=#.######; R-SQUARED=#.######; RBAR-SQUARED=#.######
821 PRINT USING 812
822 PRINT USING 814
823 PRINT USING 816,2**B7(2),B7(2),B7(2)+1,-1/(B7(2)+1)
824 PRINT USING 818,EXP(B7(1))/(B7(2)+1),EXP(B7(1))
825 PRINT USING 820,R2**(1/2),R2,1-((N-1)/(N-2))*(1-R2)
826:-------------------------------------------------------------------------
827:     LOT      CUM        X(M)     LOT TOT    LOT AVG    LOT AVG  % DIFF
828:*************************************************************************

829:  ####.#  ######  ####.####  ####.####  ##.####  ###.####  ###.##
830 PRINT USING 826
831 PRINT USING 817
832 PRINT USING 827
834 PRINT USING 828
838 FOR I=1 TO N
839 C6(I)=EXP(B7(1))*(M(I))**B7(2)
840 C5(I)=A7(I)/Q1(I)
841 PRINT USING 829,Q1(I),Q(I),M(I),A7(I),C5(I),C6(I),((C6(I)-C5(I))/C5(I))*1
00
842 NEXT I
898 M1=1
899 GO TO 1030
900 B5=R(U,2)
902 B6=R(U,2)+R(U,4)
903 A5=R(U,1)
904 A6=R(U,1)+R(U,3)
905 A5=EXP(A5)
906 A6=EXP(A6)
907 B9=R(U,2)
```

```
909 IF M(U+2)<N8 GO TO 3400
910 IF M(U+1)>N8 GO TO 3400
915 FOR I=1 TO N
920 IF Q(I)<N8 GO TO 950
930 B5=R(U,2)
940 M(I)=((Q(I)**(B5+1)-L(I)**(B5+1))/((Q(I)-L(I))*(B5+1)))**(1/B5)
945 GO TO 1000
950 IF L(I)<N8 GO TO 980
960 B5=R(U,2)+R(U,4)
970 GO TO 940
980 S2=((A5)*(N8**(B5+1)-L(I)**(B5+1)))/((B5+1)*Q1(I))
990 S3=((A6)*(Q(I)**(B6+1)-N8**(B6+1)))/((B6+1)*Q1(I))
996 M(I)=((S2+S3)/A5)**(1/B5)
997 IF M(I)<N8 GO TO 1000
998 M(I)=((S2+S3)/A6)**(1/B6)
1000 NEXT I
1030 DIM C(4)
1040 U=1
1080 FOR I=1 TO N
1090 X(I,2)=M(I)
1100 X(I,1)=1
1105 D(I)=1
1110 NEXT I
1115 FOR I=1 TO N
1120 M(I)=X(I,2)
1125 NEXT I
1200 FOR K=1 TO N-3
1220 FOR I=1 TO 1+K
1230 D(I)=0
1240 NEXT I
1400 FOR I=1 TO N
1405 X(I,2)=M(I)
1410 X(I,3)=D(I)
1412 X(I,4)=X(I,2)
1420 NEXT I
1425 SCRATCH #2
1431 FOR I=1 TO N
1432 FOR J=1 TO 4
1434 WRITE #2,X(I,J);
1435 NEXT J
1436 NEXT I
1439 RESTORE #2
1440 MAT READ #2,X(N,4)
1450 FOR I=1 TO N
1452 X(I,2)=LOG(X(I,2))
1453 X(I,4)=D(I)*LOG(X(I,4))
```

```
1470 NEXT I
1500 MAT X1=TRN(X)
1510 MAT X2=X1*X
1520 MAT X3=INV(X2)
1530 MAT X4=X3*X1
1540 MAT B=X4*Y
1545 MAT Y1=TRN(Y)
1550 MAT E1=Y1*Y
1560 MAT E2=X1*Y
1565 MAT B1=TRN(B)
1570 MAT E3=B1*E2
1575 MAT E=E1-E3
1580 MAT E4=(2)*E3
1585 MAT E5=E1-E4
1590 MAT E6=B1*X1
1595 MAT E7=TRN(E6)
1600 MAT E8=E6*E7
1605 MAT E9=E5+E8
1610 MAT F1=X*B
1615 MAT F2=E6*F1
1620 MAT F3=E6*Y
1625 MAT F3=(2)*F3
1630 MAT F4=F3-E1
1635 MAT F5=E6*F1
1640 MAT F6=F3-F5
1710 SCRATCH #1
1720 MAT WRITE #1,B,E9,F6,E1
1723 RESTORE #1
1725 MAT READ #1,P
1730 FOR I=1 TO 5
1735 R(K,I)=P(I)
1740 NEXT I
1750 R(K,6)=(P(6)-S1)/(P(7)-S1)
1760 R(K,7)=R(K,2)/((R(K,5)/(N-4))^.5*(X3(2,2)) .5)
1770 R(K,8)=R(K,3)/((R(K,5)/(N-4))^.5*(X3(3,3)) .5)
1780 R(K,9)=R(K,4)/((R(K,5)/(N-4))^.5*(X3(4,4)) .5)
1785 R(K,10)=R(K,1)/((R(K,5)/(N-4)) ^.5*(X3(1,1)) .5)
1790 IF K=1 THEN 1820
1800 IF R(K,5)>R(U,5) THEN 1820
1810 U=K
1820 NEXT K
1900 N8=EXP((-R(U,3))/R(U,4))
1910 N8=INT(1000*N8+.5)/1000
1920 M1=M1+1
1925 IF M1=30 GO TO 1980
1926 PRINT M1,B9,B6
```

```
1927 PRINT R(K,5),R(K,6)
1930 IF A5=0 GO TO 900
1931 IF M1=30 GO TO 1990
1932 IF ABS(R(U,2)-B9) >.0000005 GO TO 900
1933 IF ABS(R(U,2)+R(U,4)-B6)>.0000005 GO TO 900
1980 IF M(U+2) <N8 GO TO 3500
1981 IF M(U+1) <N8 GO TO 3500
1985 N9=N8
1990 PRINT
1991 PRINT
1992 PRINT
1993 PRINT
2000 PRINT "            SPLIT LEARNING CURVES"
2005 PRINT
2010 PRINT " EQUATION FORM Y=e^(A1+A2*DUM1)*X^(B1+B2*DUM1)"
2015 PRINT
2019:     'LLLLLLLL      'LLLLLLLLLL      'LLLLLLLLLL
2020:     'LLLLLLLL      #####.######     ####.###
2021 U1$="VARIABLE"
2022 U2$="COEFFICIENT"
2023 U3$="T-STATISTIC"
2025 PRINT USING 2019,U1$,U2$,U3$
2029 U$=" A1"
2030 PRINT USING 2020,U$,R(U,1),R(U,10)
2039 U$=" A2"
2040 PRINT USING 2020,U$,R(U,3),R(U,8)
2049 U$=" B1"
2050 PRINT USING 2020,U$,R(U,2),R(U,7)
2059 U$=" B2"
2060 PRINT USING 2020,U$,R(U,4),R(U,9)
2070 PRINT
2071 IF ABS(R(U,8)) <T(N-4) GO TO 3340
2072 IF ABS(R(U,9))>T(N-4) GO TO 3340
2073 PRINT "THE ABSOLUTE VALUE OF THE T-STATISTIC FO A2 AND B2"
2074 PRINT "EXCEEDS ";T(N-4) "THESE VARIABLES, THEN, ARE"
2075 PRINT "SIGNIFICANT AT THE 95% CONFIDENCE LIMIT AND THERE EXISTS"
2077 PRINT " A SPLIT LEARNING CURVE"
2079 PRINT
2080 PRINT " R-SQUARED ";R(U,6)
2085 PRINT " RBAR-SQUARED ";1-((N-1)/(N-4))*(1-R(U,6))
2090 PRINT " RESIDUAL SUM OF SQUARES ";R(U,5)
2100 PRINT
2110 PRINT " FIRST ";U+1;" POINTS ON FIRST CURVE,REMAINDER ON SECOND"
2120 PRINT " ALL VALUES LESS THAN ";N9;" PREDICTED FROM FIRST CURVE"
2130 PRINT " ALL VALUES GREATER THAN ";N9;" PREDICTED FROM SECOND CURVE"
2140 PRINT
```

```
2150:              'LL          'LLLLLLLLLLL      'LLLL       'LLLLLLL     'LLL
2160:   'LLLLLL  ###.####      ###.####       #.###        ##.######   ##.######
2170 U1$="T1"
2172 U2$="SLOPE"
2174 U3$="B-VALUE"
2175 U6$="Y-INTERCEPT"
2176 U4$="CURVE1"
2178 U5$="CURVE2"
2179 U7$="B+1"
2180 PRINT USING 2150,U1$,U6$,U2$,U3$,U7$
2190 PRINT USING 2160,U4$,A5/(B9+1),A5,EXP(B9*LOG(2.0)),B9,B9+1
2200 PRINT USING 2160,U5$,A6/(B6+1),A6,EXP(B6*LOG(2.0)),B6,B6+1
2500:         'LLLLL          'LLLLLLLLLLLLLLL
2510:         #####.#          ########.####
2590 PRINT
2595 PRINT
2600 PRINT USING 817
2602 PRINT USING 827
2603 PRINT USING 828
2605 FOR I=1 TO N
2610 IF Q(I)>N9 GO TO 2640
2630 PRINT USING 829,Q1(I),Q(I),M(I),A7(I),A7(I)/Q1(I),A5*M(I)**B9,((A5*M(I)*
*B9-A7(I)/Q1(I))/(A7(I)/Q1(I)))*100
2635 GO TO 2650
2640 PRINT USING 829,Q1(I),Q(I),M(I),A7(I),A7(I)/Q1(I),A6*(M(I))**B6,((A6*M(I
)**B6-A7(I)/Q1(I))/(A7(I)/Q1(I)))*100
2650 NEXT I
2900 PRINT
2920:                              PREDICTIONS
2925 PRINT USING 2920
2930 PRINT USING 826
2940:    LOT     CUM      UNIT       TOT LOT    LOT AVG    CUM TOT     CUM AVG
2945 PRINT USING 2940
2947 PRINT USING 828
2950:  ####.#  ######  ###.####  #####.#### ###.####  ########.##  ###.####
2955 I=1
2959 N1=B9+1
2960 N2=B6+1
2961 N3=A5/N1
2962 N4=A6/N2
2975 I=1
3000 C=Q2(I)
3005 IF C=9010000001 GO TO 9000
3006 DATA 9010000001
3010 IF I=1 GO TO 3040
3020 Q3(I)=C-Q2(I-1)
3030 GO TO 3050
3040 Q3(1)=Q2(1)
```

```
3050 IF C>N9 GO TO 3160
3060 C1=N3*C**N1-N3*(C-1)**N1
3080 C2=N3*C**N1
3090 IF I=1 GO TO 3120
3100 C3=C2-N3*Q2(I-1)**N1
3110 GO TO 3130
3120 C3=C2
3130 C4=C3/Q3(I)
3140 C5=C2/Q2(I)
3150 GO TO 3300
3160 C1=N4*C**N2-N4*(C-1)**N2
3170 D3=N4*C**N2-N4*N9**N2
3180 D4=N3*N9**N1
3190 C2=D3+D4
3200 C5=C2/Q2(I)
3210 IF I=1 GO TO 3260
3220 IF Q2(I-1)<N9 GO TO 3280
3230 C3=C2-(N4*Q2(I-1)**N2-N4*N9**N2+N3*N9**N1)
3240 C4=C3/Q3(I)
3250 GO TO 3300
3260 C3=C2
3270 C4=C3/Q2(I)
3275 GO TO 3300
3280 C3=C2-N3*Q2(I-1)**N1
3290 C4=C3/Q3(I)
3300 PRINT USING 2950,Q3(I),Q2(I),C1,C3,C4,C2,C5
3310 I=I+1
3320 GO TO 3000
3330 GO TO 900
3340 PRINT "THE ABSOLUTE VALUE OF THE T-STATISTIC FOR A2 AND/OR"
3342 PRINT "B2 DOES NOT EXCEED ";T(N-4) "THESE VARIABLES ARE NOT"
3344 PRINT "SIGNIFICANT AT THE 95% CONFIDENCE LIMIT AND THEREFORE,"
3346 PRINT "A SPLIT LEARNING CURVE DOES NOT EXIST."
3350 GO TO 2079
3400 FOR I=1 TO N
3410 IF I>U+1 GO TO 3450
3420 M(I)=((Q(I)**(B9+1)-L(I)**(B9+1))/(Q1(I)*(B9+1)))**(1/B9)
3430 GO TO 3480
3450 M(I)=((Q(I)**(B6+1)-L(I)**(B6+1))/(Q1(I)*(B6+1)))**(1/B6)
3480 NEXT I
3490 GO TO 1030
3500 N9=Q(U+1)
3510 GO TO 1990
9000 END
```

Two Splits

```
10 DIM T(30)
12 FOR I=1 TO 30
14 READ T(I)
16 NEXT I
17 DATA 12.706,4.303,3.182,2.776,2.571,2.447,2.365,2.306,2.262,2.228
18 DATA 2.201,2.179,2.16,2.145,2.131,2.12,2.11,2.101,2.093,2.086
19 DATA 2.08,2.074,2.069,2.064,2.06,2.056,2.052,2.048,2.045,2.042
40 REM SPLIT LEARNING CURVE PROGRAM
45 REM AT LEAST SEVEN AND PREFERABLY MORE DATA POINTS NEEDED
50 REM USE DATA STATEMENTS BETWEEN LINES 100 AND 1000 TO INPUT DATA
52 REM ENTER THE NUMBER OF DATA POINTS THEN
55 REM FIRST PUT IN ALL COST OR HOUR DATA(LOT TOTALS),NEXT THEIR RESPECTIVE
60 REM CUMULATIVE QUANTITIES (BEGINNING AND END) ,THIRDLY, CUMULATIVE
65 REM QUANTITIES FROM WHICH YOU WISH TO PREDICT
80 DIM A7(50),A8(50),Q(50),M(50),Z(50,2),Z1(2,50),Z2(2,2),Z3(2,2)
81 DIM Z4(2,50),B7(2),P(9),X1(50,50),X4(50,50),Y1(50,50),Y(50)
82 DIM X(50,6),D(50),P1(2),C5(50),C6(50),L(50),Q1(50),R4(1,50)
83 DIM Q2(50),Q3(50),R(40,14),R1(40,14),D2(50)
84 DIM P7(50),T7(50)
85 DIM R2(40,14)
86 DIM E6(50,50),E7(50,50)
87 DIM F1(50)
88 DIM F3(1,50)
89 DIM H1(1,4)
90 DIM C1(50),C3(50),C4(50),C2(50)
100 DATA 24
110 DATA 17.5,14.0,13.5,12.5,13.0,12.5,13.0,14.5,11.0,13.0,57.5,48.5
111 DATA 41.3,33.8,58.0,48.0,40.0,37,37,36,33,32,31.5,30.5
120 DATA 0,1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,15,15,20,20,25
121 DATA 25,30,30,40,40,50,50,60,60,70,70,80,80,90,90,100,100,110,110,120,120
,130
130 DATA 10,20,30,40,50,60,70,80,90,100,300
500 READ N
505 FILES M2;M3
510 FOR I=1 TO N
520 READ A7(I)
530 NEXT I
535 SCRATCH #2
540 FOR I=1 TO N
550 READ L(I),Q(I)
552 Q1(I)=Q(I)-L(I)
560 A8(I)=A7(I)/Q1(I)
565 A8(I)=LOG(A8(I))
567 WRITE #2,A8(I)
```

```
570 NEXT I
572 FOR I=2 TO 1000
573 READ Q2(I)
574 IF Q2(I)=9010000001 THEN 580
576 NEXT I
580 S1=0
590 FOR I=1 TO N
596 RESTORE #2
597 MAT READ #2,Y(N)
610 S1=S1+Y(I)
612 NEXT I
615 S1=S1**2
620 S1=S1/N
630 B5=-.9
640 FOR I=1 TO N
650 M(I)=((Q(I)**(B5+1)-L(I)**(B5+1))/(Q1(I)*(B5+1)))**(1/B5)
660 Z(I,2)=M(I)
670 Z(I,2)=LOG(Z(I,2))
680 Z(I,1)=1
690 NEXT I
691 SCRATCH #2
692 FOR I=1 TO N
693 FOR J=1 TO 2
694 WRITE #2,Z(I,J)
695 NEXT J
696 NEXT I
697 RESTORE #2
698 MAT READ #2,Z(N,2)
700 MAT Z1=TRN(Z)
710 MAT Z2=Z1*Z
720 MAT Z3=INV(Z2)
730 MAT Z4=Z3*Z1
740 MAT B7=Z4*Y
750 IF ABS(B7(2)-B5)<.0000005 GO TO 780
760 B5=B7(2)
770 GO TO 640
780 MAT B8=TRN(B7)
782 MAT R4=B8*Z1
784 MAT R3=R4*Y
786 MAT Y1=TRN(Y)
788 MAT Y2=Y1*Y
789 MAT H1=B8*Z2
790 MAT H2=H1*B7
791 MAT H3=(2)*R3
792 MAT H4=Y2-H3
793 MAT H5=H4+H2
```

```
794 MAT H6=Y2-R3
795 SCRATCH #2
796 MAT WRITE #2,Y2,R3
797 RESTORE #2
798 MAT READ #2,P1
810 R2=(P1(2)-S1)/(P1(1)-S1)
812: UNIFIED LOG-LINEAR PROGRESS CURVE FORMULATION-ALL CURVES ARE LINEAR
814: LINEAR LEAST SQUARES ANALYSES OF UNIT CURVE-NTH UNITS AT MIDPOINTS
816: SLOPES; PERCENT=###.###; B=#.#####; B+1=#.#####;-1/B+1=##.####
817:                                    ACTUAL     ACTUAL     CALC
818: FIRST UNIT COST ######.#####; Y-INT. OF LIN UNIT CURVE ####.#####
820:  R=#.######; R-SQUARED=#.######; RBAR-SQUARED=#.######
821 PRINT USING 812
822 PRINT USING 814
823 PRINT USING 816,2**B7(2),B7(2),B7(2)+1,-1/(B7(2)+1)
824 PRINT USING 818,EXP(B7(1))/(B7(2)+1),EXP(B7(1))
826:
827:  LOT       CUM       X(M)        LOT TOT     LOT AVG   LOT AVG   %DIFF
828: ************************************************************************
829: ####.#   ######   ####.####   ####.####   ###.####   ###.####   ###.##
830 PRINT USING 826
831 PRINT USING 817
832 PRINT USING 827
834 PRINT USING 828
838 FOR I= 1 TO N
839 C6(I)=EXP(B7(1))*(M(I))**B7(2)
840 C5(I)=A7(I)/Q1(I)
841 PRINT USING 829,Q1(I),Q(I),M(I),A7(I),C5(I),C6(I),((C6(I)-C5(I))/C5(I))*1
00
842 NEXT I
843 M1=1
845 GO TO 1030
900 B5=R1(U,2)
901 B6=B5+R1(U,4)
902 B9=B6+R1(U,6)
903 A4=EXP(R1(U,1))
904 A5=EXP(R1(U,1)+R1(U,3))
905 A6=EXP(R1(U,1)+R1(U,3)+R1(U,5))
915 GO SUB 3600
1030 DIM C(6)
1040 U=1
1080 FOR I=1 TO N
1090 X(I,2)=M(I)
1100 X(I,1)=1
1110 NEXT I
1115 V=1
1170 FOR L=1 TO N-5
```

```
1171 FOR I=1 TO N
1172 D2(I)=1
1173 NEXT I
1175 FOR I=1 TO N-(L+1)
1180 D2(I)=0
1185 NEXT I
1200 FOR K=1 TO N-(4+L)
1205 FOR I=1 TO N
1206 D(I)=1
1207 NEXT I
1220 FOR I=1 TO 1+K
1230 D(I)=0
1240 NEXT I
1400 FOR I=1 TO N
1405 X(I,2)=M(I)
1410 X(I,3)=D(I)
1412 X(I,4)=X(I,2)
1414 X(I,5)=D2(I)
1416 X(I,6)=X(I,2)
1420 NEXT I
1425 SCRATCH #2
1431 FOR I=1 TO N
1432 FOR J=1 TO 6
1434 WRITE #2,X(I,J);
1435 NEXT J
1436 NEXT I
1439 RESTORE #2
1440 MAT READ #2,X(N,6)
1450 FOR I=1 TO N
1452 X(I,2)=LOG(X(I,2))
1453 X(I,4)=D(I)*LOG(X(I,4))
1460 X(I,6)=D2(I)*LOG(X(I,6))
1470 NEXT I
1500 MAT X1=TRN(X)
1510 MAT X2=X1*X
1520 MAT X3=INV(X2)
1530 MAT X4=X3*X1
1540 MAT B=X4*Y
1545 MAT Y1=TRN(Y)
1550 MAT E1=Y1*Y
1560 MAT E2=X1*Y
1565 MAT B1=TRN(B)
1570 MAT E3=B1*E2
1580 MAT E4=(2)*E3
1585 MAT E5=E1-E4
1590 MAT E6=B1*X1
```

```
1595 MAT E7=TRN(E6)
1600 MAT E8=E6*E7
1605 MAT E9=E5+E8
1640 MAT F6=E4-E8
1710 SCRATCH #1
1720 MAT WRITE #1,B,E9,F6,E1;
1723 RESTORE #1
1725 MAT READ #1,P
1730 FOR I=1 TO 7
1735 R(K,I)=P(I)
1740 NEXT I
1750 R(K,8)=(P(8)-S1)/(P(9)-S1)
1755 IF R(K,7)=0 GO TO 7000
1760 R(K,9)=R(K,2)/((R(K,7)/(N-4))^.5*(X3(2,2))^.5)
1770 R(K,10)=R(K,3)/((R(K,7)/(N-4))^.5*(X3(3,3))^.5)
1780 R(K,11)=R(K,4)/((R(K,7)/(N-4))^.5*(X3(4,4))^.5)
1782 R(K,12)=R(K,5)/((R(K,7)/(N-4))^.5*(X3(5,5))^.5)
1783 R(K,13)=R(K,6)/((R(K,7)/(N-4))^.5*(X3(6,6))^.5)
1785 R(K,14)=R(K,1)/((R(K,7)/(N-4))^.5*(X3(1,1))^.5)
1790 IF K=1 THEN 1820
1791 IF R2(V,7)=0 THEN 1800
1792 IF R(K,7)>R2(V,7) THEN 1820
1793 GO TO 1810
1800 IF R(K,7)>R(V,7) THEN 1820
1810 V=K
1815 R2(V,7)=R(V,7)
1820 NEXT K
1825 FOR Q=1 TO 14
1830 R1(L,Q)=R(V.Q)
1835 NEXT Q
1850 IF L=1 THEN 1890
1859 IF R1(L,7)=R1(U,7) THEN 1890
1860 IF R1(L,7)>R1(U,7) THEN 1890
1865 U=L
1890 NEXT L
1900 N8=EXP((-R1(U,3))/R1(U,4))
1920 N9=EXP(-R1(U,5)/R1(U,6))
1935 IF M1=2 GO TO 1980
1940 M1=M1+1
1950 IF A5=0 GO TO 900
1955 IF ABS(R1(U,2)-B5)>.0000005 GO TO 900
1960 IF ABS(R1(U,2)+R1(U,4)-B6)>.0000005 GO TO 900
1965 IF ABS(R1(U,2)+R1(U,4)+R1(U,6)-B9)>.0000005 GO TO 900
1980 B5=R1(U,2)
1981 B6=B5+R1(U,4)
1982 B9=B6+R1(U,6)
```

```
1983 A4=EXP(R1(U,1))
1984 A5=EXP(R1(U,1)+R1(U,3))
1985 A6=EXP(R1(U,1)+R1(U,3)+R1(U,5))
1990 GO SUB 3600
1991 PRINT
1992 PRINT
1993 PRINT
1994 PRINT
2000 PRINT "            SPLIT LEARNING CURVES"
2005 PRINT
2010 PRINT " EQUATION FORM Y=e^(A1+A2*DUM1+A3*DUM2)*X^(B1+B2*DUM1+B3*DUM2)"
2015 PRINT
2019:     'LLLLLLLL     'LLLLLLLLLLL     'LLLLLLLLLL
2020:     'LLLLLLLL     #####.######     ######.##
2021 U1$="VARIABLE"
2022 U2$="COEFFICIENT"
2023 U3$="T-STATISTIC"
2025 PRINT USING 2019,U1$,U2$,U3$
2029 U$=" A1"
2030 PRINT USING 2020,U$,R1(U,1),R1(U,14)
2039 U$=" A2"
2040 PRINT USING 2020,U$,R1(U,3),R1(U,10)
2042 U$=" A3"
2044 PRINT USING 2020,U$,R1(U,5),R1(U,12)
2049 U$=" B1"
2050 PRINT USING 2020,U$,R1(U,2),R1(U,9)
2059 U$=" B2"
2060 PRINT USING 2020,U$,R1(U,4),R1(U,11)
2062 U$=" B3"
2064 PRINT USING 2020,U$,R1(U,6),R1(U,13)
2070 PRINT
2072 PRINT " IF ABSOLUTE VALUE OF T-STATISTIC EXCEEDS ";T(N-6)
2074 PRINT " FOR THE DUMMY VARIABLES A2,A3,B2,AND B3, THEN THESE VARIABLES"
2075 PRINT " ARE SIGNIFICANT AT 95% CONFIDENCE LIMIT AND THERE EXISTS"
2077 PRINT " A TWICE SPLIT LEARNING CURVE"
2079 PRINT
2080 PRINT " R-SQUARED ";R1(U,8)
2090 PRINT " RESIDUAL SUM OF SQUARES ";R1(U,7)
2100 PRINT
2110 PRINT "FIRST ";V+1;"POINTS ON FIRST CURVE, NEXT ";N-V-U-2
2115 PRINT "POINTS ON SECOND, NEXT ";U+1;" ON THIRD"
2120 PRINT " ALL VALUES LESS THAN ";N8;" PREDICTED FROM FIRST CURVE"
2125 PRINT " ALL VALUES LESS THAN ";N9;" BUT GREATER OR EQUAL TO ";N8
2127 PRINT " ARE PREDICTED FROM THE SECOND CURVE, WHILE"
2130 PRINT " ALL VALUES GREATER THAN ";N9;" PREDICTED FROM THIRD CURVE"
2135 PRINT "THE PROGRAM HAS COMPLETED ";M1; "ITERATIONS"
```

```
2140 PRINT
2150:              'LL      'LLLLLLLLLLL 'LLLLL  'LLLLLLL      'LLL
2160:  'LLLLLL   ###.####       ###.####  #.###  ##.######  ##.######
2170 U1$="T1"
2172 U2$="SLOPE"
2174 U3$="B-VALUE"
2175 U6$="Y-INTERCEPT"
2176 U4$="CURVE1"
2177 U7$="B+1"
2178 U5$="CURVE2"
2179 Q9$="CURVE3"
2180 PRINT USING 2150,U1$,U6$,U2$,U3$,U7$
2190 PRINT USING 2160,U4$,A4/(B5+1),A4,EXP(B5*LOG(2.0)),B5,B5+1
2200 PRINT USING 2160,U5$,A5/(B6+1),A5,EXP(B6*LOG(2.0)),B6,B6+1
2210 PRINT USING 2160,Q9$,A6/(B9+1),A6,EXP(B9*LOG(2.0)),B9,B9+1
2500:         'LLLLL          'LLLLLLLLLLLLLLL
2510:         #####.#          ########.####
2590 PRINT
2591 PRINT
2592 PRINT
2600 PRINT USING 817
2602 PRINT USING 827
2603 PRINT USING 828
2605 FOR I=1 TO N
2610 P7(I)=((T7(I)-EXP(A8(I)))/EXP(A8(I)))*100
2620 PRINT USING 829,Q1(I),Q(I),M(I),A7(I),EXP(A8(I)),T7(I),P7(I)
2630 NEXT I
2900 PRINT
2903 PRINT
2905 PRINT
2910:                    PREDICTIONS
2915 N8=INT(N8+.5)
2916 N9=INT(N9+.5)
2920 PRINT USING 2910
2930 PRINT USING 826
2940:   LOT      CUM     UNIT         TOT LOT        LOT AVG    CUM TOT      CUM A
VG
2945 PRINT USING 2940
2947 PRINT USING 828
2950:  ####.#  ###### ###.####  ######.####  ###.####  ########.##  ###.####
2959 M5=B5+1
2960 M6=B6+1
2961 M9=B9+1
2962 N4=A4/M5
2963 N5=A5/M6
2964 N6=A6/M9
2975 I=2
```

```
2976 Q2(1)=0
2977 C2(1)=0
2980 F1=N4*N8**M5
2990 F2=N5*N8**M6
3000 F3=N5*N9**M6
3010 F4=N6*N9**M9
3020 IF Q2(I)=9010000001 GO TO 9000
3030 Q3(I)=Q2(I)-Q2(I-1)
3040 DATA 9010000001
3050 IF Q2(I)>N9 GO TO 3130
3060 IF Q2(I)>N8 GO TO 3100
3070 C2(I)=N4*Q2(I)**M5
3080 C1(I)=C2(I)-N4*(Q2(I)-1)**M5
3090 GO TO 3150
3100 C2(I)=N5*Q2(I)**M6-F2+F1
3110 C1(I)=C2(I)-N5*(Q2(I)-1)**M6+F2-F1
3120 GO TO 3150
3130 C2(I)=N6*Q2(I)**M9-F4+F3-F2+F1
3140 C1(I)=C2(I)-N6*(Q2(I)-1)**M9+F4-F3+F2-F1
3150 C5(I)=C2(I)/Q2(I)
3160 C3(I)=C2(I)-C2(I-1)
3170 C4(I)=C3(I)/Q3(I)
3500 PRINT USING 2950,Q3(I),Q2(I),C1(I),C3(I),C4(I),C2(I),C5(I)
3510 I=I+1
3520 GO TO 3000
3600 GO TO 3720
3601 FOR I=1 TO V
3625 M(I)=((Q(I)**(B5+1)-L(I)**(B5+1))/(Q1(I)*(B5+1)))**(1/B5)
3627 T7(I)=A4*M(I)**B5
3629 NEXT I
3630 FOR I=V+2 TO N-U-2
3650 M(I)=((Q(I)**(B6+1)-L(I)**(B6+1))/(Q1(I)*(B6+1)))**(1/B6)
3652 T7(I)=A5*M(I)**B6
3655 NEXT I
3660 FOR I=N-U TO N
3700 M(I)=((Q(I)**(B9+1)-L(I)**(B9+1))/(Q1(I)*(B9+1)))**(1/B9)
3705 T7(I)=A6*M(I)**B9
3710 NEXT I
3715 RETURN
3720 IF Q(V+1)<N8 GO TO 3900
3730 IF L(V+1)>N8 GO TO 3900
3740 S2=(A4*(N8**(B5+1)-L(V+1)**(B5+1)))/(B5+1)
3750 S3=(A5*(Q(V+1)**(B6+1)-N8**(B6+1)))/(B6+1)
3760 M(V+1)=((S2+S3)/(A4*Q1(V+1)))**(1/B5)
3765 T7(V+1)=A4*M(V+1)**B5
3770 IF M(V+1)<N8 GO TO 3790
```

END

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